Honeywell

ALT-GTS-Stem Fabrication

Federal Manufacturing & Technologies

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Final Report

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T. Nguyen, Project Leader

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Abstract

In 2007, a study investigated options to manufacture stems utilizing methods that would replace crush form grinding while maintaining or improving quality at a comparative cost. Crush form grinding is a special process used at the Kansas City Plant to finish stem sections of reservoir products. However, crush form grinding is a complex process with many variables affecting the final product. This study identified two potential methods that can be applied to stems. Profile grinding was investigated in 2007. This project continued in 2008 proving that single point turning on a multi-turret is an option with additional benefits. It is an economical way to meet floor space limitations for our KCRIMS mission.

Summary

Crush form grinding has been used at the Kansas City Plant for years to finish stems with thin wall and sharp radii. Stem diameters have always tapered between 0.0010 to 0.0020 inches dating back to the 1980s. In the last five years, significant effort has been put forth to try to reduce or eliminate this issue. A new crush form grinder was purchased during the fourth quarter of 2005, yet the problem was not totally eliminated. The taper of the stem using the new grinder could not consistently maintain the 0.0010 inches requirement limit even with the support of a steady rest.

This project was started in 2007 to identify potential methods of finishing stems while sustaining, or preferably enhancing, quality as compared to crush form grinding. Two methods were considered promising: profile grinding and single point turning. Profile grinding was tested in 2007 on a Kellenberger Varia with some limitations.

The continuation of this project in 2008 was to validate the single point turning method on a multi-turret lathe, a Traub TNX 65/42 manufactured by INDEX Corporation. INDEX agreed to perform tests with specimens provided by FM&T. By March 2008, KCP learned that INDEX machinery was incapable of meeting the needed requirements. The machine does not consistently drill a 0.0625 inch through hole due to design limitations of the high pressure pump. It is able to finish turn the entire configuration of the most complicated stem currently being crush ground at KCP. The stem taper is within 0.0002 inch and stem roundness is 0.0003 inch. The last ten specimens were all free of mismatches. An additional advantage of this method is that it eliminates cross hatched marks on flat surfaces caused by the sides of the grinding wheel. At the end, this project proved that a Traub TNX 65/424 could successfully single point turn the outside stem configuration of a 1X stem, but its current design failed to drill the through hole in the stem.

Discussion

Scope and Purpose

The purpose of this report is to document a project which verified the method of single point turning to finish machine stems. The project performed and evaluated test cuts on specimens using a Traub TNX 65/42 at the INDEX plant in Indiana.

Prior Work

See KCP-613-8368 titled "GTS Stem Fabrication". This paper documents work that was performed in FY2007 for a project, which evaluated, selected, and validated some processes that can potentially be used to finish stems as an optional method. Details on profile grinding are found in this report.

Activity

This project was started in FY 2007 to select a potential method to finish stems in Reservoir system.

Profile grinding and single point turning were the two most promising methods as determined by using the House of Design Quality (QFD). Profile grinding was tested on a Kellenberger Varia in Switzerland. The result was not successful since there were burrs, shape changes at corners, taper above 0.0010 inches, and a machining time longer than current crush form grinding. Single point turning was tested with some success.

INDEX Corporation was then contacted in order for further tests to be conducted on a lathe. A Traub TNX 65/42 with a capacity of 40 tools on four turrets was suggested by INDEX for tests to make the 1X stem configuration.

Background

The option of profile grinding did not provide reliable and stable results. There were at least three grinding wheels involved in the process. Two main issues were minimum taper of 0.001 inches and corners of the wheel maintaining sharp form as the result of traverse motion. Other concerns were the number of wheels to handle and burrs.

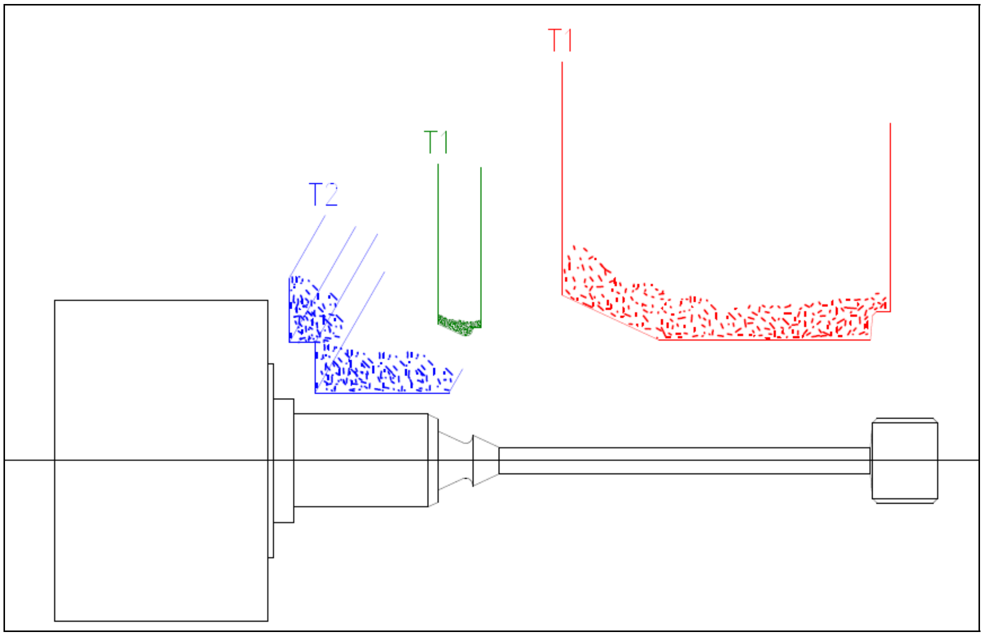


Figure 1. Wheel profiles and illustration of grinding sequence on Kellenberger Varia.

A reason for the failure was that the machine was not a suitable one. It was designed for work-pieces up to 150 kg (330 lbs). Additionally, the machine would be costly (about $750,000) with no advantage in run time and part dimensions compared to the existing crush form grinder.

Figure 2. A Kellenberger Varia.

Issues

This year, funds were received to evaluate the option of finishing machine 1X stems by single point turning. In order to justify the results, it was decided to use forged material as WR products. Issues are expected as a normal factor in any project.

- ✓ Limit number of forged material and funds. Only enough stock material for current reservoir process requirements was purchased.
- ✓ Communication with INDEX technician. At the beginning, there was no direct contact with the technician who programmed and machined specimens. Currently there is email contact for any questions and concerns with a response time within one day.
- ✓ INDEX scrapped about half of specimens in each group we sent during setup and adjustment. They provided stainless steel bar stock to finish proving program and dimensions.
- ✓ High pressure pump provided maximum 120 bars of pressure. This pressure is not enough to flood chips out of the gun-drilling hole. The result was high run-out and scrapped specimens with broken drills.

Test Specimens

Initially, KCP engineering planned to test machine capability only for the outside configuration of the 1X stem. The INDEX engineer also suggested drilling the through hole in the stem. The final contract was for INDEX to machine two groups of specimens for KCP.
The first group of eleven specimens were drilled and qualified in KCP so INDEX just machined the outside configuration. Specimens in this group were identified with sequential serial numbers. Five out of the eleven specimens were scrapped out during setup and machining at INDEX. Taper on the 0.1235-inch diameter of the remaining specimens was not impressive. It was as low as 0.0003 inches and as high as 0.0018 inches (*see* Table 1). X-ray results performed at KCP showed all six passed inspection on diametrically opposed wall thickness.

Table 1: Dimensions of 11 specimens in the first group machined at INDEX and measured at KCP.

S/N	BASE HEIGHT	BASE HEIGHT	0.0960 STEP	0.7725 STEP	BASE DIAMETER	STEM BODY DIAMETER (BODY END)	STEM BODY DIAMETER (GROOVE END)	STEM DIA. (GROOVE END)	STEM DIA. (MIDDLE)	STEM DIA. (THREAD END)
	High	Low	0.096	0.7725	Ø0.577	Ø0.433	Ø0.433	Ø0.1235	Ø0.1235	Ø0.1235
	± 0.002	± 0.003	± 0.002	± 0.002	± 0.002	± .001	± .001	±.0015	±.0015	±.0015
	H. Gage	H. Gage	H. Gage	H. Gage	Laser Mic	Laser Mic.				
1	0.3496	0.3496	0.0959	0.7738	0.0002	-0.0007	-0.0007	0.001	0.0002	-0.0004
2										
3										
4										
5										
6										
7	0.3534	0.3517	0.0962	0.772	0.0005	0.0001	-0.0001	0.0003	0.0005	0.0006
8	0.3543	0.3528	0.0954	0.7723	0	0.0002	0.0001	-0.0001	0.0006	0.0004
9	0.3476	0.3469	0.0956	0.7726	0.0004	0.0003	0.0002	0.0001	0.0005	0.0005
10	0.3495	0.3480	0.0970	0.7734	0.0002	0.0003	0.0002	-0.0001	0.0006	0.0004
11	0.3544	0.3536	0.0963	0.773	0.0002	0.0003	0.0002	0.0023	0.0023	0.0005

The second group of eleven specimens was rough turned to the same shape and size as the first. INDEX would drill and then finish the outside stem of this second group to prove out their drilling capability. Specimens in this second group were again identified with sequential serial numbers. Results from group one testing were sent to INDEX as feedback. Again five samples were scrapped at INDEX. Some were scrapped because gun-drills broke. These parts were drilled with water based coolant and surface finish was unacceptable. Taper on the 0.1235-inch diameter was still up to 0.0018 inches (*see* Table 2). Comparison of both sets of results shows little improvement.

Table 2: Deviated values of diameters measured at KCP using laser micrometer.

S/N	BASE HEIGHT	BASE HEIGHT	0.0960 STEP	0.7725 STEP	BASE DIAMETER	STEM BODY DIAMETER (BODY END)	STEM BODY DIAMETER (GROOVE END)	STEM DIA. (GROOVE END)	STEM DIA. (MIDDLE)	STEM DIA. (THREAD END)
	High	Low	0.096	0.7725	Ø0.577	Ø0.433	Ø0.433	Ø0.1235	Ø0.1235	Ø0.1235
	± 0.002	± 0.003	± 0.002	± 0.002	± 0.002	± .001	± .001	±.0015	±.0015	±.0015
	H. Gage	H. Gage	H. Gage	H. Gage	Laser Mic	Laser Mic.				
1	0.3555	0.3546	0.0972	0.7725	0.0000	0.0003	-0.0003	0.0011	0.0005	-0.0006
2	0.3558	0.3548	0.0970	0.7723	-0.0001	-0.0007	-0.0005	0.0010	0.0003	-0.0002
3	0.2558	0.3551	0.0970	0.7724	-0.0002	-0.0002	-0.0009	0.0013	0.0003	-0.0002
4	0.3560	0.3551	0.0970	0.7723	-0.0002	-0.0001	-0.0008	0.0012	0.0003	-0.0001
5	0.3557	0.3553	0.0965	0.7720	0.0000	-0.0001	-0.0002	0.0013	0.0005	-0.0006
6	0.3507	0.3502	0.0960	0.7736	0.0001	-0.0001	-0.0003	0.0010	0.0003	-0.0007
7										
8										
9										
10										
11										

After receiving feedback from KCP, INDEX began to use Swiss Silver oil. According to Cutting Edge Fluids, “Swiss Silver is a light amber, bright, clear, and low viscosity mineral-base oil. The unique formulation of this product results in low foam, low smoke fluid that is cleaner than standard oils used in Swiss style CNC turning machines. Since it is a clear liquid it provides optimum visibility for the machine operator.”

Swiss Silver oil has the following properties:

Specific gravity @ 60°F	0.92
Pounds/Gallon	7.60
Viscosity SUS @ 100°F	85
Appearance	Light Amber Liquid
Flash Point	Over 365°F

With this oil, INDEX was able to drill holes with an acceptable surface finish. The problem, as predicted, was that drills tended to break pre-maturely. It was then determined that alignment and oil pressure were two parameters that should be investigated. After technicians at INDEX verified that tools and turrets were well aligned our team then tried to increase oil pressure. The current gun-drills, TC1470106-021, allowed the least flow of oil compared to the EDMed drills ordered by INDEX.

According to the gun-drill vendor, oil flow should be approximately 0.20 to 0.22 gallons per minute for 0.0625-inch diameter gun-drills. At this time, there are only 0.078 gallons per minute of 50/50 oil flowing through TC1470106-021. The TC1470106-021 drills were made by Drill Masters Eldorado Tool. Similar tests on 0.0625-inch diameter drills made by Nagel Precision Incorporation provided a flow rate of 0.120 gallons per minute.

To prove out that the machine can drill the 0.0625 inch through hole, INDEX performed extra work on a stainless steel bar-stock. The result was promising with a total run-out reading (TIR) as low as 0.001 inches (and as high as 0.009 inches.)

Benefits and Issues

Currently, there are seven steps in the Stem Cell to completely machine a stem from its forged stock to final dimensions:

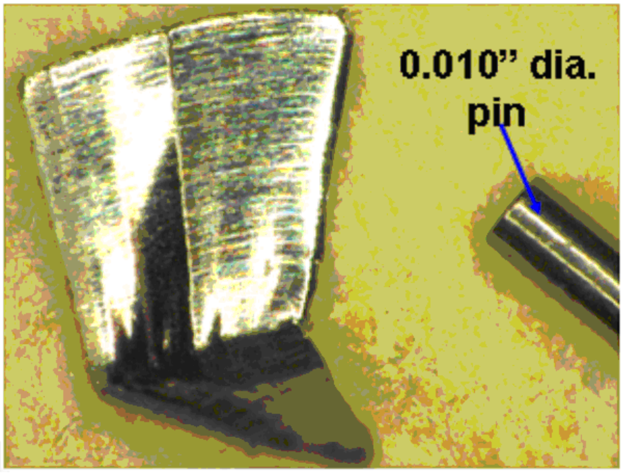
- Rough turning on Hardinge T51: remove forged hard skin to relieve stress. (15 to 45 minutes)
- Gun-drilling on Nagel twin spindle: drill the through hole along the axis of part. (5 minutes)
- Qualifying on Hardinge HLV: machine an outside diameter concentric to the hole and a flat surface perpendicular to the hole to establish datums to finish turning part. (10 minutes)
- Finish turning on Hardinge T51: finish machining the body and threads, semi-finish the stem. (20 to 60 minutes)
- Rough conical seat cutting on Hardinge HLV: single point turning the conical seat to be concentric to the hole. (10 minutes)
- Crush form grinding on Hardinge HLV: grind the entire stem portion to finished dimensions. (15 to 30 minutes)
- Finish conical seat cutting on Hardinge HLV: re-cut or polish the conical seat. (10 minutes)

Figure 3: Machines in Stem cell

In general, it takes between 85 minutes to 170 minutes to completely machine a single part. For a 1X test stem, current total machining time is 125 minutes. INDEX reported that after rough turning and qualifying they can finish turning the stem in 20 minutes. This could cut the total machining time to 80 minutes, a 37.5% gain.

Additional time could be saved if the hole could be drilled in the Traub. According to INDEX Corporation, the current design of the Traub TNX 65/42 does not allow pressure higher than 120 bars. In the future, if there is a similar machine with higher pressure capability, or if optimum settings can be found on the Traub TNX 65/42 that allow it to reach a pressure higher than 120 bars, runtime could be decreased 56%.

The ability to control Gun-drilling processes has always been a big concern. The Gun-drill used in the Gas Transfer System is only 0.0625 inches in diameter and it needs to drill up to almost 4.00 inches deep. That means the length, L (depth) is up to 64 times the drill diameter, D. Gun-drilling chips vary in size and can be as large as 0.050 inches and as long as 0.120 inches. In order for chips to be quickly removed from the hole, high pressure oil flow is a must. Jammed chips can plug up the flute resulting in drill breakage.



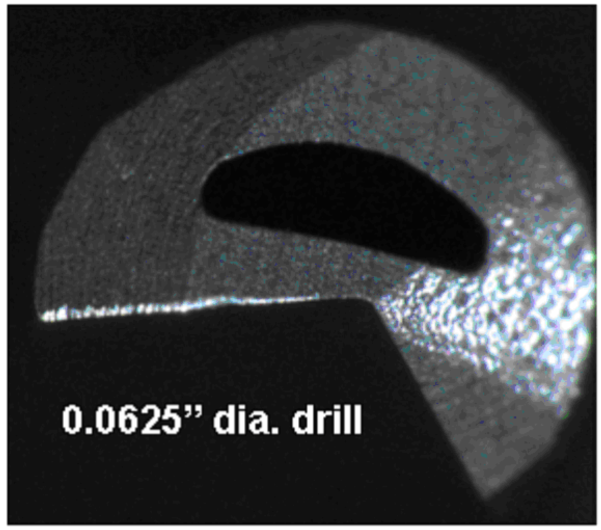


Figure 4: Chips can be as large as the entire drill diameter.

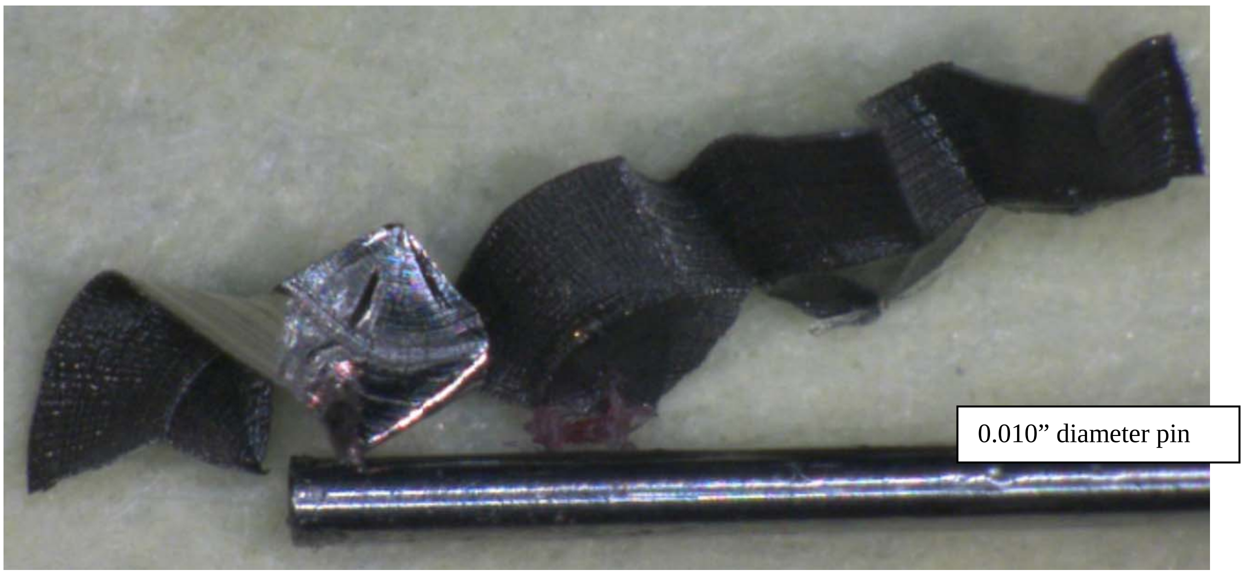


Figure 5: Chip can be 0.120" about twice the drill diameter.

At this time, a "Flip-Flop" operation is utilized at rough and finish turning in the Stem Cell. With this practice, two lathe operations are combined into one setup. A part will be machined on one end then flipped over to be machined on the opposite end. It is very critical to bore two concentric diameters at the same time on a single set of jaws. Machinists have a tendency to re-cut only one diameter which is worn or damaged. This behavior results in high run-out and large variation in wall thickness. Using two spindles eliminates the necessity of concentricity of bored diameters and simplifies the machinists' task.

The following are concerns of not finishing the stem with a crush form grinding method. In crush form grinding, the entire costly form is ground and thoroughly inspected. There is no chance for any mismatch. Any error that happens may result in the whole order having the same defect. With single point turning, there is a high chance of mismatch due to multiple tools being used on many sections along the length of the stem. Of course, a repeating defect is possible but with lower quantity.

The biggest concern from an engineering stand point is a lack of available skill set to operate this type of machine. From the experience of operating two 8-axis INDEX machines, the plant will have a difficult time employing suitable analysts and machinists for this new challenge.

Considering all the advantages and issues learned during this project, there are two potential outcomes.

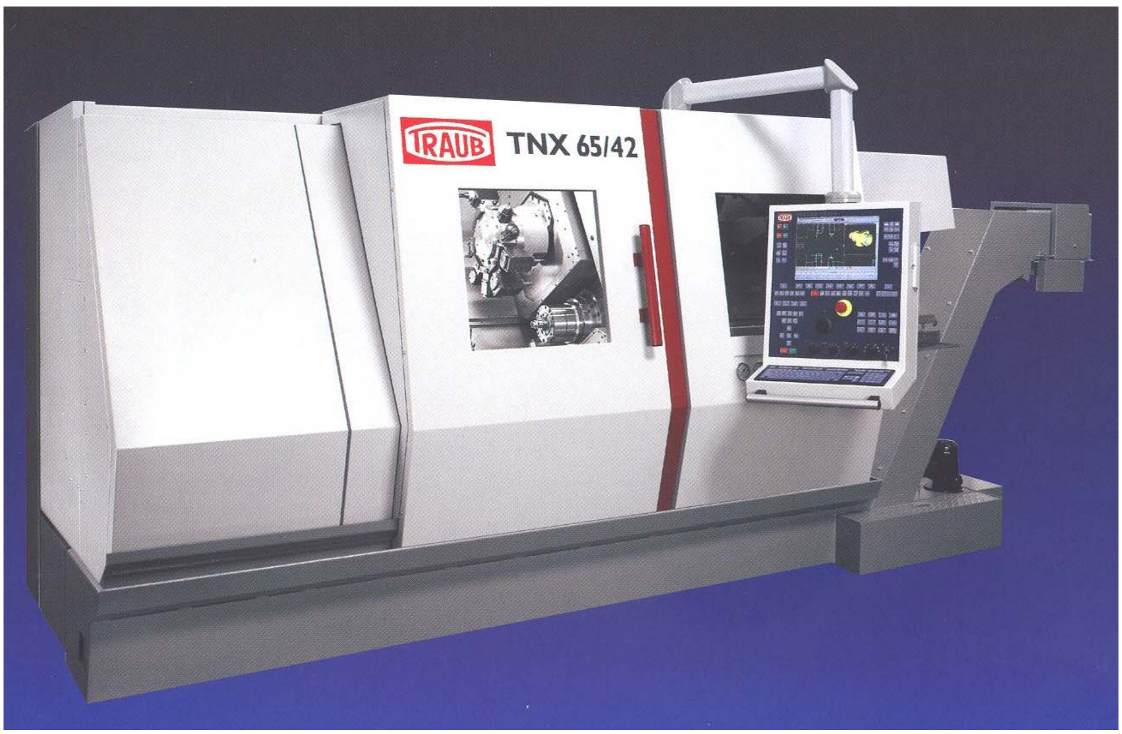


Figure 6: A Traub TNX 65/42

Outcome 01: Purchase a Traub TNX 65/42 to replace a slantbed, an HLV, and crush form grinder. Floor space will then be down to a third of the current occupancy. The advantages of purchasing a Traub TNX 65/42 are that it has four turrets and is capable of engaging up to three tools at any time. To finish turn the stem, two turn tools are engaged at the same time with a supporting live center loaded on the third turret. This practice helps to reduce bending in the stem under cutting force. The result is that taper of the 0.1235-inch diameter stem is within 0.0003 inches. Rough tool is approximately 0.100 to 0.200 inches ahead of the finish tool. In this case, two cutting forces do not create large force on the stem. The fact is the rough tool provides support and shortens the stem beam, helping the finish turn tool to machine the stem better. This application is superior to the turning described in report KCP-613-8368. There will be no mismatch since the finish tool constantly engages on the stem and finishes on a single pass.

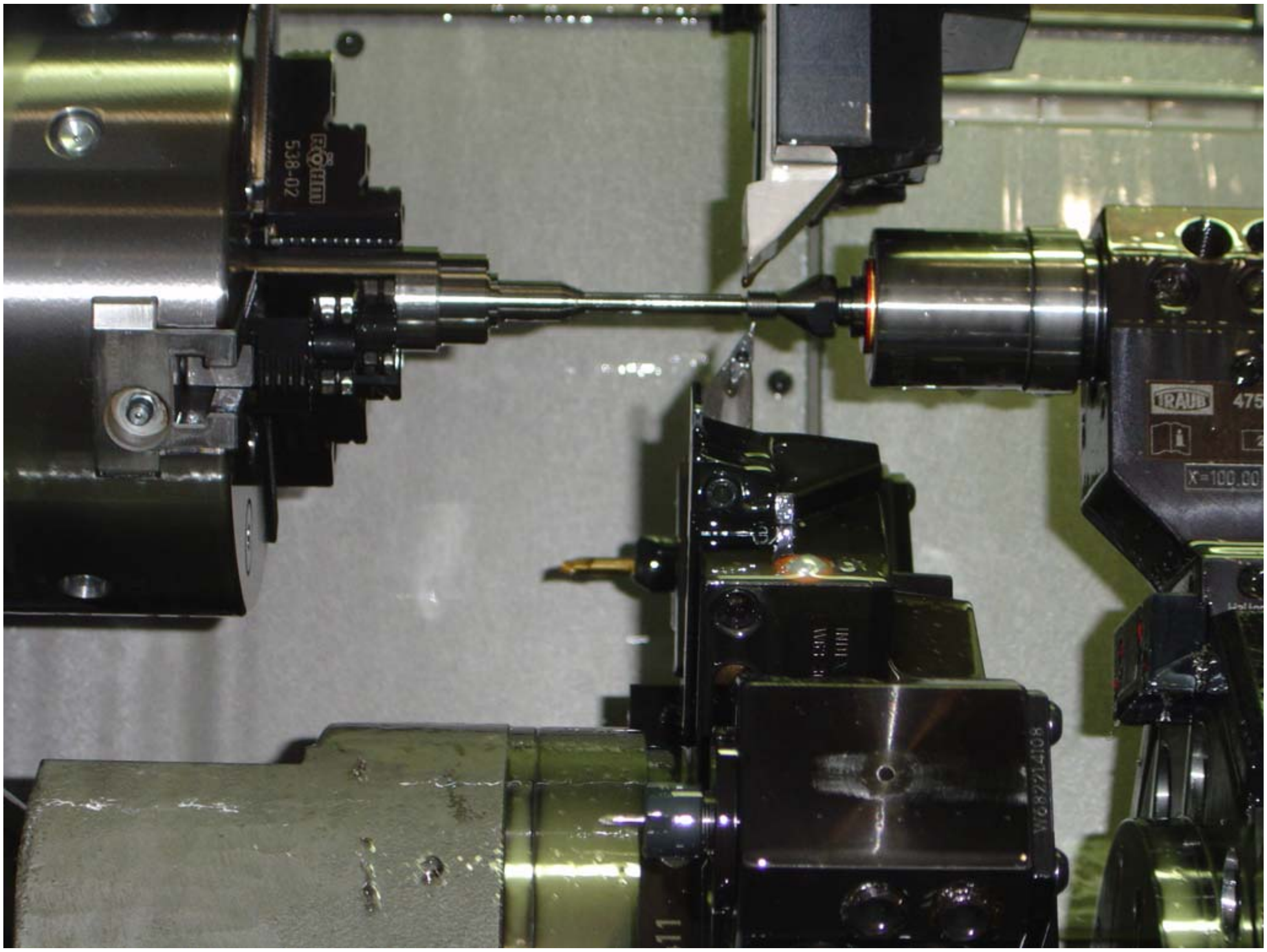


Figure 7: Two cutting tools engaged simultaneously with a live center on the third spindle

Upgrading to proposed Outcome 01 has many benefits. The first benefit is being able to reduce the current processes from seven down to five operations. This saves shop floor time and space and helps machinists to easily arrange their work. Only three machinists would be needed to cover the Stem cell in proposed Outcome 01. One machinist would rough turn the part while the second would start the gun-drill machine. The first one would then move to the qualifying operation as the second covers the finish conical seat operation. The third machinist would spend full time at the Traub.

Outcome 02: An official from INDEX Corporation informed that a 160-bar pressure tool-holder is being engineered at INDEX. According to INDEX the current limiting factor is in the tool holder itself. Potentially, oil (coolant) supply to a gun-drill would be coming through the turret using the hydraulic lines. With the option of applying a 160-bar pressure tool-holder, five operations could be combined into one—multi-axis turning—leaving rough turning and finishing conical seat operations as is (*see* Figure 8). If this action is achieved, machining processes in the Stem cell can be reduced up to 80% and floor space reduced 75%.

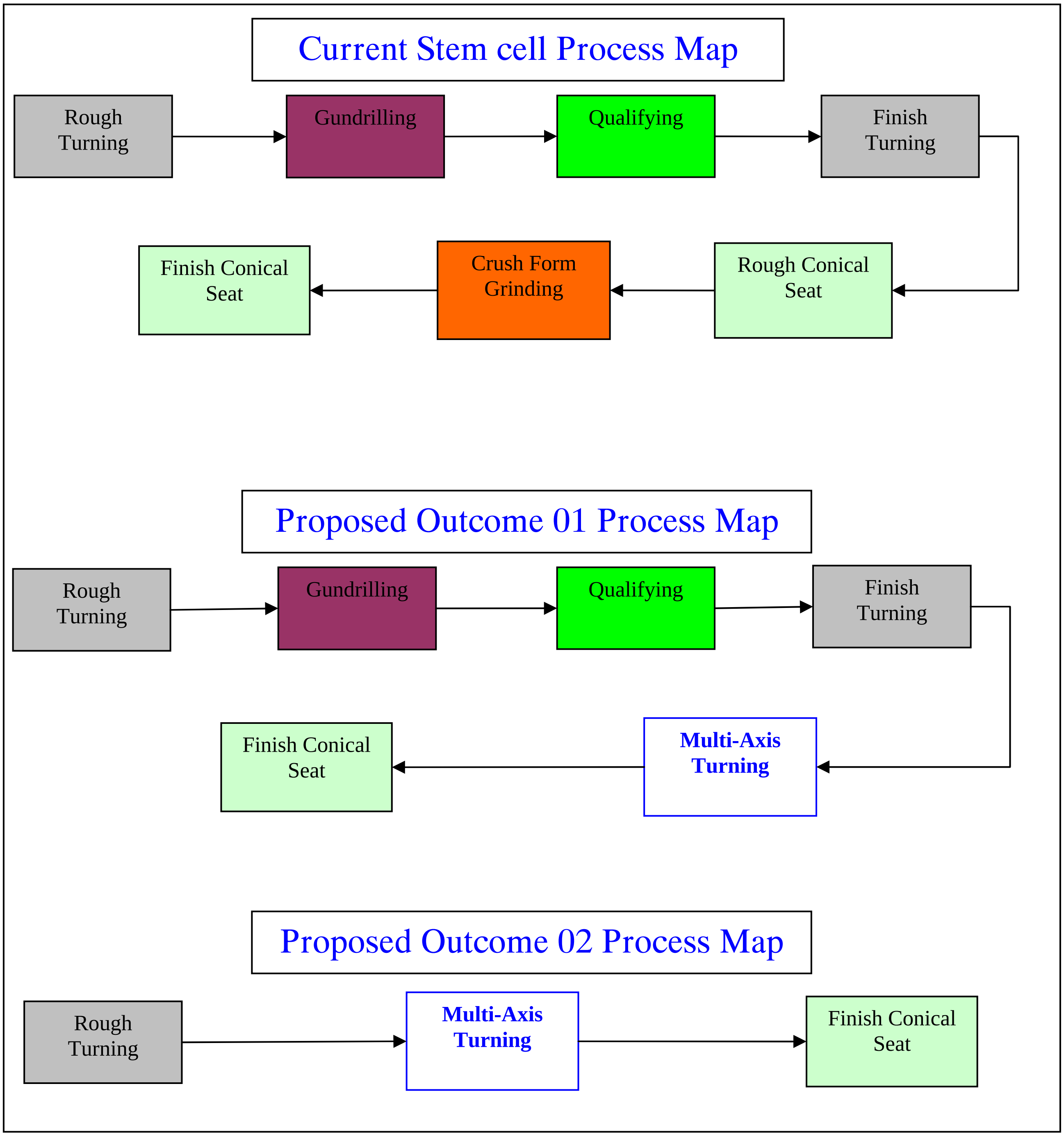


Figure 8: Stem Cell Process Maps _ current, proposed outcome 01, proposed outcome 02.

If proposed Outcome 02 is applied, only two machinists are needed in the cell. That means with four machinists, two identical production lines can be setup for parallel processes, thus, doubling outputs.

Accomplishments

Crush form grinding has been used to finish stems in Gas Transfer Systems for years. When it was originally developed, it was considered an advanced process providing a consistent profile of output. However, as tolerances tighten and machines age it has become increasingly difficult to keep the process of crush form grinding under control. Tight tolerances and/or more complicated forms multiply setup and adjusting times at machines. Currently, it can take up to 16 hours to change crush rolls and get back to production on the 1X and 2X. Single point turning on a multiple turret machine is one possible solution, especially for 1X and 2X stems. Groove features of these stems have been defined in drawing with tolerances to cover mismatch of a turning operation. In a typical single point turning process, two or three features are finished by a cutting tool. Machinists can easily identify and adjust for those dimensions. In general, any machine has some advantages and disadvantages when compared to other machines. Furthermore, the trend of technology requires skilled machinists on any process. This is particularly true when the process requires tight tolerances and complicated forms. With fewer operations in the proposed Stem cell process, fewer resources are needed while still achieving the same level of quality.

Future Work

Gun-drilling is still a challenging operation. Understanding this process will help to further improve yield in Gas Transfer System. More study is needed to bring proposed Outcome 02 to reality. This will take time and depends on the availability of the machine manufacturer. Other vital elements to study for stable process of single point turning on multiple axis machines are: good positive rake cutting tools to reduce shear forces, advanced coating, and/or cutting tools material that will keep the process more stable. As process stability increases the chance for machinist error decreases, and, as a result, there is better quality of product.